

The science and practice of river restoration

Wohl, E., S. N. Lane, and A. C. Wilcox (2015), *The science and practice of river restoration*, *Water Resour. Res.*, 51, 5974–5997, doi:10.1002/ 2014WR016874.



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Example of river restoration through removal of grade-control structures along the Mareit River, Italy.

Introduction

- **Review** article from 2015

- Science



- Advancements in last 50 years
- River restoration (RR) prominent area
- RR serves as a fundamental **testing ground** for scientific knowledge of rivers

- Economy and society

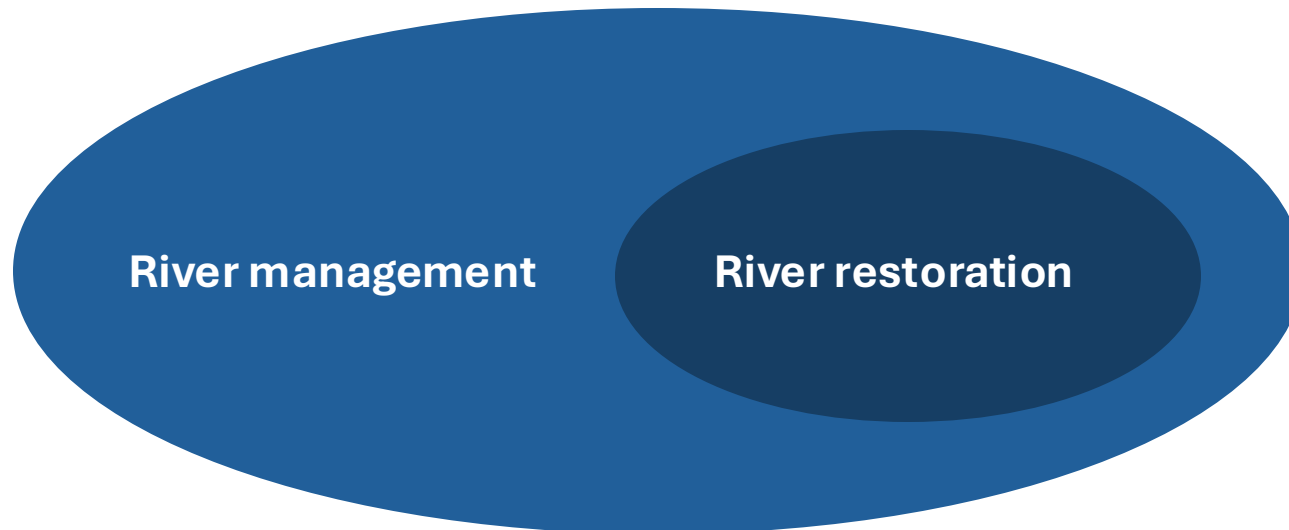


- Multibillion dollar **industry** across multiple countries
- **Public interest** in restoring rivers

What is river restoration?

Def.: Refers to a wide range of modifications to river channels, riparian zones, floodplains, and inputs like water, sediment, and solutes, aimed at improving degraded watershed processes.

- Goals: Enhancing hydrologic, geomorphic, and ecological processes
- Reconnection vs. Reconfiguration
- Improvements are very **subjective**



*Attempts to create or maintain some aspect of river form and functions that are **desirable apart from hazard reduction***

What is river restoration?

Table 1. Common River Restoration Goals^a

Goal	Description
Esthetics/recreation/education	Activities that increase community value: use, appearance, access, safety, and knowledge
Bank stabilization	Practices designed to reduce or eliminate erosion or slumping of bank material into the river channel; this category does not include stormwater management
Channel reconfiguration	Alteration of channel geometry, planform, and/or longitudinal profile and/or daylighting (converting pipes or culverts to open channels); includes meander restoration and in-channel structures that alter the thalweg
Dam removal/retrofit	Removal of dams and weirs or modifications/retrofits to existing dams to reduce negative impacts; excludes dam modifications that are simply for improving fish passage
Fish passage	Removal of barriers to upstream/downstream migration of fishes; includes the physical removal of barriers, construction of alternative pathways, and migration barriers placed at strategic locations along streams to prevent undesirable species from accessing upstream areas
Floodplain reconnection	Practices that increase the inundation frequency, magnitude, or duration of floodplain areas and/or promote fluxes of organisms and materials between channels and floodplain areas
Flow modification	Practices that alter the timing and delivery of water quantity (does not stormwater management); typically but not necessarily associated with releases from impoundments and constructed flow regulators
Instream habitat improvement	Altering structural complexity to increase habitat availability and diversity for target organisms and provision of breeding habitat and refugia from disturbance and predation
Instream species management	Practices that directly alter aquatic native species distribution and abundance through the addition (stocking) or translocation of animal and plant species and/or removal of exotic species; excludes physical manipulations of habitat/breeding territory
Land acquisition	Practices that obtain lease/title/easements for streamside land for the explicit purpose of preservation or removal of impacting agents and/or to facilitate future restoration projects

^aDefinitions from National River Restoration Science Synthesis Project.

Structure of article

Historical development of RR



Current Scope of RR:
Small to Medium Sized Rivers
Medium-sized to Large Rivers



Critical perspectives on RR:

1. Problem of Conceptualization
2. Interface Science and Society
3. Challenges of Science



Conclusion

Historical developments of river restoration

Increase in river restorations: **recognition of river alteration**

19th century

Esthetic and recreational purposes



Fish oriented restoration

- **physical manipulation** of the channel form
- **bioengineering** using plants

20th century

Reduction of the **risk of loss of life and property**
Enhanced **navigation**



Water quality-oriented restoration

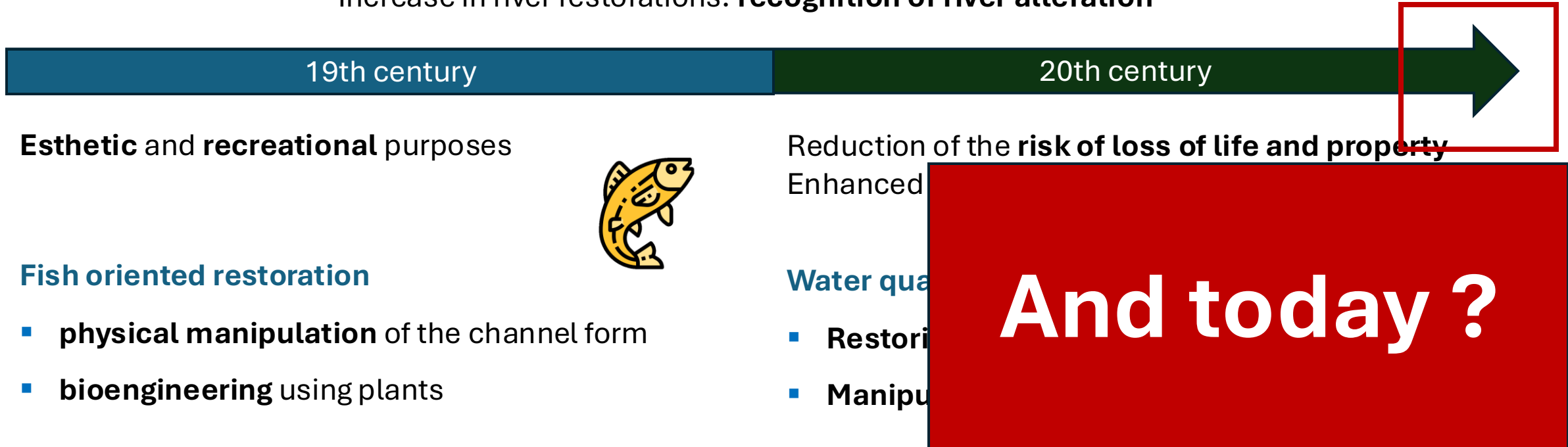
- **Restoring riparian corridors and floodplains**
- **Manipulating flow and channel form**

USA 1972 **Clean Water Act**

European Union 2000 **Water Framework Directive**

Historical developments of river restoration

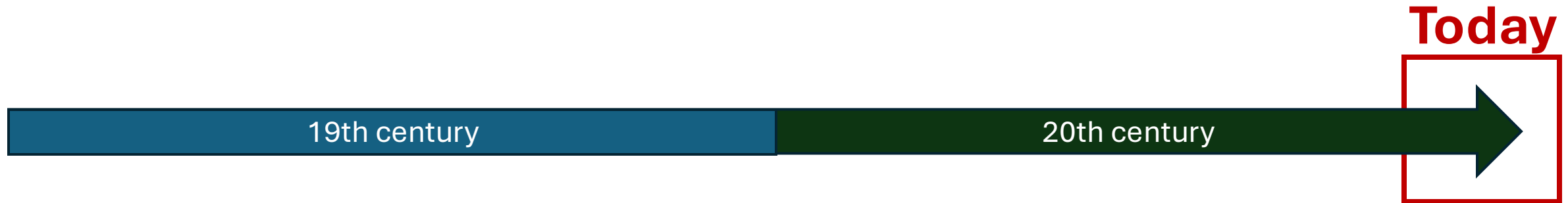
Increase in river restorations: **recognition of river alteration**



USA 1972 **Clean Water Act**

European Union 2000 **Water Framework Directive**

Current scope of river restoration



Today: **Process-based restoration**

- Channel-floodplain, longitudinal **connectivity**
- Partial restoration of **water and sediment fluxes**
- **Ecological productivity**

Evaluated with respect to **biotic response**

RR **acceleration** in the past 3 decades (USA, Europe, Australia)

Broader range of river types (e.g., headwater, hydropeaking, large drainage networks,...)

Small to-medium-sized rivers



Medium-sized to large rivers



Small to-medium-sized rivers



Steep streams

Goals:

- Stabilization
- organic matter retention
- macroinvertebrates richness
- Diversity

Limits:

- Limited nitrogen removal for step-pool channels in urban settings with lower-gradient headwater (no erosion during high flows)

Urban river naturalisation:

Goals:

- water quality
- infrastructure protection

Challenges:

- urban infrastructure
- potentially large hydraulic forces

Limits:

- reach scale not sufficient

Justification of costs:

- recreational & aesthetic benefits
- Enhanced public awareness

Agricultural areas:

Goals:

- water quality
- contaminants retention
- removal for different flow conditions

Challenges:

- position in the watershed
- hyporheic exchanges
- flow regime
- nitrogen concentrations

Example of measure:

- limit riparian grazing
- hyporheic restoration
- reconnection to the floodplain and bank protection

Medium-sized to large rivers



Goals:

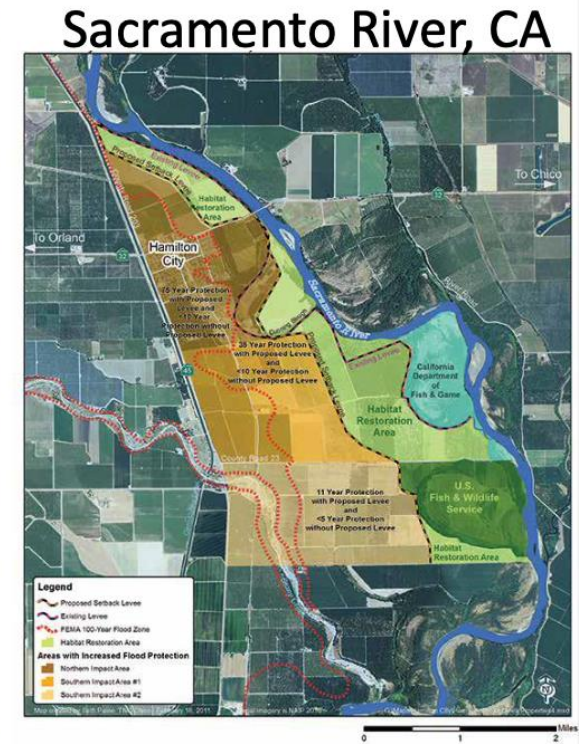
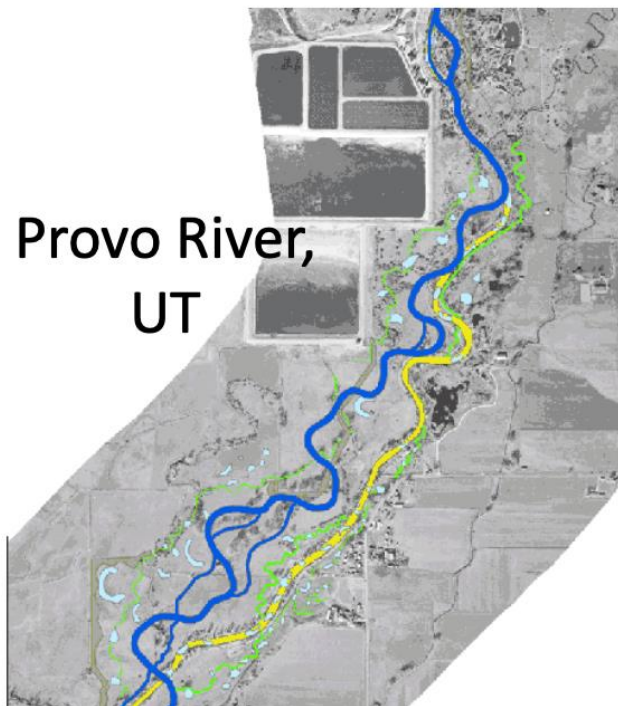
- reduce flooding **hazards**
- restore river-floodplain habitat **connectivity**
- associated **ecosystem**
- geomorphic **processes**

Expectations:

- increased water quality
- benthic habitat and ecosystem function
- affecting the food chain & species richness

Examples of measures: dams removal, grade-control removals,...

Medium-sized to large rivers



Critical Perspectives on RR: 3 Challenges

Problem of
conceptualization and how
we approach RR



Developing RR projects at
the interface of science
and society



Science of restoration
itself



1) Problem of conceptualization : how do we approach RR ?



Identifying restoration **goals**:

- Based on an appropriate model of ecosystem response, as well as the recovery of biotic community composition
- Aim to restore a dynamic state (spatial/temporal variation in biotic abundance)
- Consider resilience (sustainability) during RR !



1) Problem of conceptualization : 3 kinds of interventions

Field of dreams

Restoring the forms of the river that have been lost

example :

Constructing artificial meanders to replicate historical structure (aesthetic and restore habitat form without restoring processes)



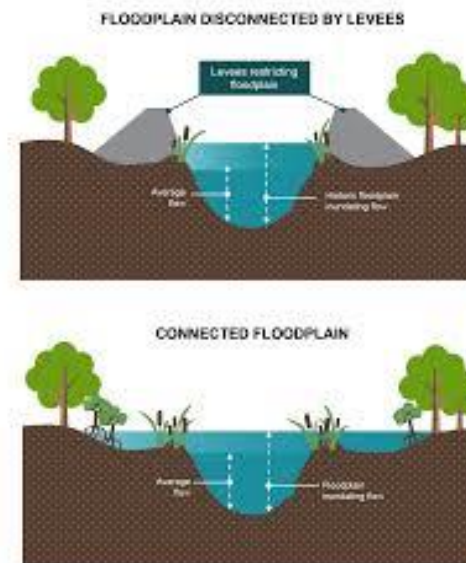
Small scale

System function

Restoring the desired process

example :

Reconnecting a river to its floodplain (flooding and sediment deposition)



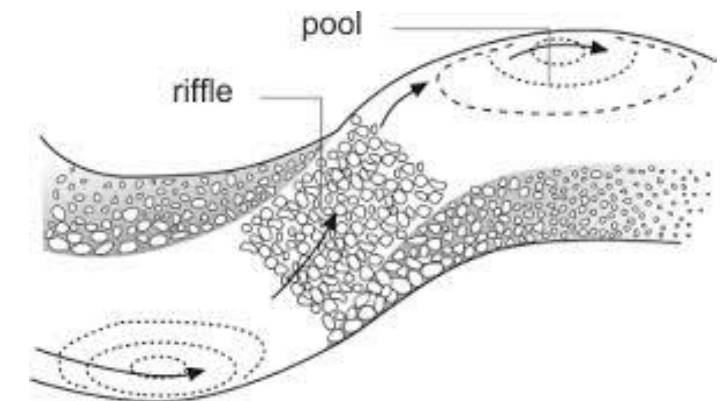
U.S. Army Corps of Engineers (USACE) and Federal Emergency Management Agency (FEMA). *National Levee Safety Guidelines: Overview*. March 2024

Hybrid RR

Both the structure and the function of a river may need to be restored

example :

Restoring riffle-pool sequences & re-establishing natural flow regimes (enhance physical habitat and aquatic ecosystem)



"Riffle and Pool." *River Styles*, 2024

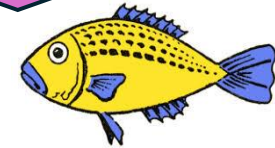
Larger scale



2) The critical challenge of the Science-Society Interface

- **Who** should be involved in setting objectives ?
 - local population (in floodplains)
 - Wider democratic question: Who decides ?
- Ecological restoration did not originate as an academic science but as a citizen-led, **public project**
- **When** can the public interfere during the project ?
 - Upstream: Setting objectives
 - Downstream: Once project proposal is given
- Limits ?

Who speaks
for me ?



Developing a sustained
interest of local communities
in river restoration



Maintaining
community support
for the project



Necessary funds, action



3) Challenges for scientific understanding in RR

- **Persisting gaps** in scientific understanding of the ecological and physical processes, and of the **feedbacks** among them
- Great need to characterize **response curves** of different river components
Example : river scientists typically cannot predict exactly what benefits will result in terms of greater recruitment of fish or riparian vegetation
- Incorporating **climate change** considerations and **resiliency** into restoration planning
Example : create thermal refugia for animals



3) Challenges for scientific understanding in RR

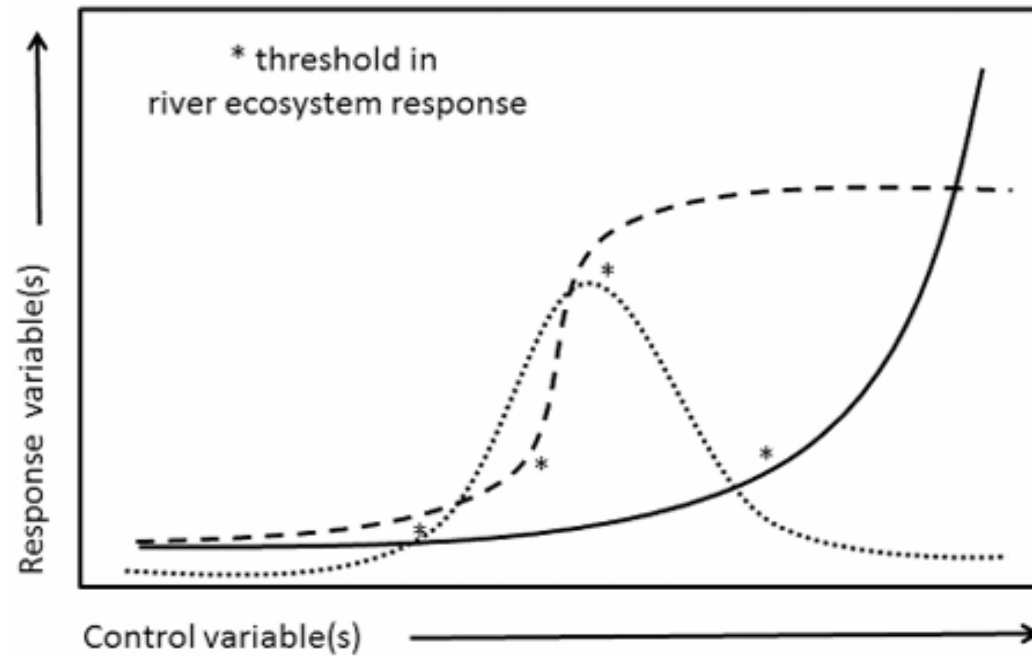


Figure 4. Illustration of hypothetical response curves

- Okavango River basin (southern Africa) : more than **4000 individual response curves** were incorporated into a Decision Support System to **evaluate the river ecosystem response** to diverse scenarios of flow regulation
- Determining **where and when** restoration is likely to have a **significant beneficial effect** on stream ecology or water quality

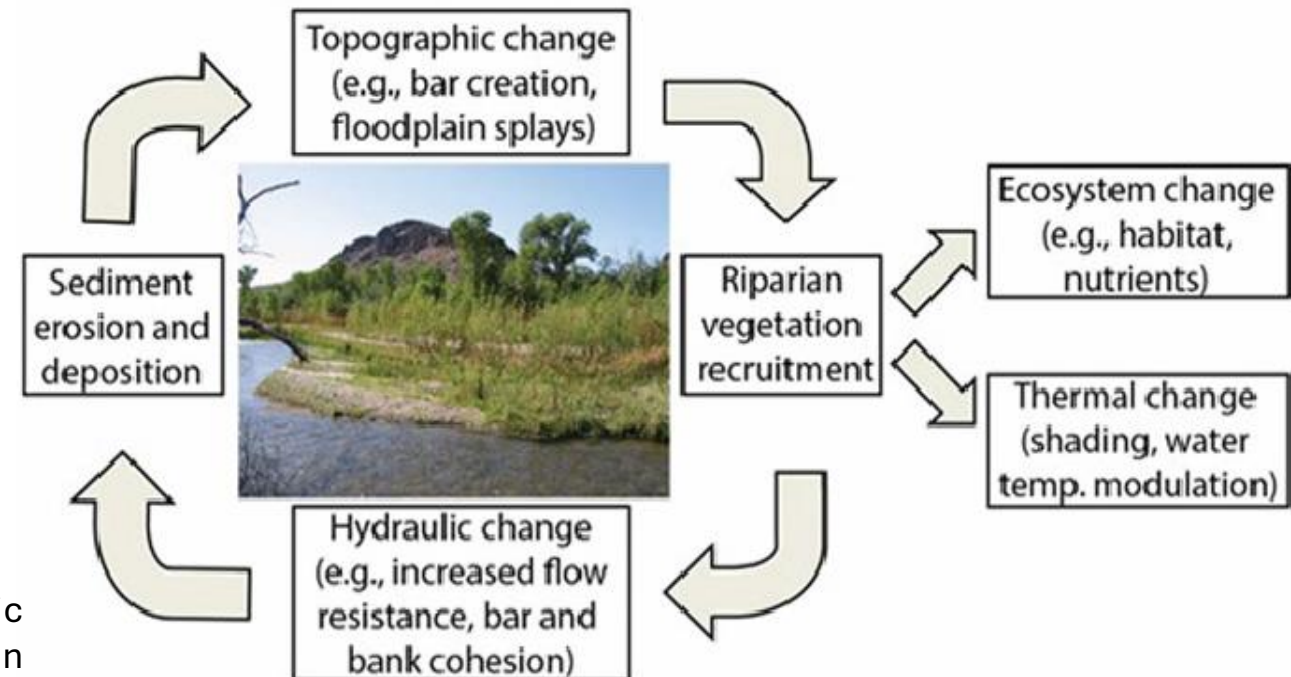


Figure 5. Illustration of one set of potential ecogeomorphic feedbacks associated with restoration

Conclusion

Actual realizations provide a **testing ground** for:

Scientific understanding of rivers

Societal attitudes toward rivers

Humanity's ability to sustain river ecosystems



Why ?

- Return to pre-human alteration conditions **when possible**
- Enhance **self-maintaining potential** of the river & its potential to **provide ecosystem services**



Old map of the Mississippi meanders

Process

Difficulties: case specific

- Recognition of physical and biological process
- Diversity and complexity of connectivity and interactions
- History
- Collaboration between river scientists and restoration practitioners

Limits:

- Focus on ecosystem services: treating symptoms rather than the problem

Results

Criteria for ecologically successful restoration

- Ecological condition measurably improved
- Self-sustaining and resilient ecosystem
- Little maintenance needed
- Consideration of social meaning and management of environment

Majority of realizations **do not respect them**

Conclusion

Reconnection efforts

- Restoring **flow and sediment** regimes
- Physically **reconnecting** floodplains
- Reintroducing **natural ecosystem engineers** (beavers)



more successful than

Globally:

- ☹ Divergence between **scales of alteration** and scales of **restoration**
- ☹ Gap between **society's** and **scientist's expectations**

→ cosmetic restorations instead of maintaining variable inputs and river forms

Reconfiguration efforts

- **Reach scale:** no effective restoration of river functional integrity (water quality and biological communities)
- BUT community participation raises (false?) **awareness**





Questions ?